A Critical Review on River Engineering Projects as a Basis for River Restoration of Korea[1)]

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〈Contents〉

초록

본 논문의 목적은 우리나라의 전통적 하천정비 공법 적용 현황 및 생태적 문제점을 조사하고, 최근에 시행된 자연형하천공법 적용 결과를 평가하는 것이다. 전통적 하천정비기법 적용 대상지는 서울의 한강, 청주 무심천, 대구 신천, 광주 광주천, 강릉 남대천을 조사하였고, 하천복원공법 대상지는 과천의 양재천, 서울 여의천, 안양 안양천, 수원 수원천을 조사하였다.

전통적 하천정비기법은 다음과 같이 하천생태계에 부작용을 초래한다. 첫째, 복단면 조성에 의한 하천정비는 저수로의 육수생태계를 축소, 단순화시키고, 고수부지는 건성초지로 변화시킨다. 따라서 다양한 하천생태계는 현저히 파괴되고, 저수호안 및 보 등의 구조물에 의하여 주변과 단절된다. 둘째, 하천정비의 결과 도시고속도로, 주차장, 자전거도로, 운동장 등의 원래의 하천생태계와 상충되는 인공시설물이 과도한 면적을 점유하여 육수생태계의 기능을 약화시킨다. 셋째, 잔디, 농작물, 초화류 등의 집약적 관리를 필요로 하는 식생을 도입하고, 자연식생의 발달을

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저해하고 있다.

자연형하천정비기법의 적용결과는 다음과 같다. 첫째, 저수로의 굴곡, 여울과 소의 조성, 다양한 저질의 형성을 목적으로 하는 공법이 적용되고 있다. 둘째, 저수호안은 버드나무, 야자섬유망, 말뚝 등의 식물재료와 자연석 등을 활용하여 다양한 서식공간 조성 및 치수상의 안전성을 도모하고 있다. 셋째, 고수부지는 산책로, 자전거로, 운동장 등의 야외휴게활동공간으로 이용되며, 생태적 복원에 대한 배려는 미흡하다. 따라서 향후의 자연형하천정비는 고수부지 및 하천 인접지역의 주요한 서식지를 네트워크로 연결하여 생태적 이동통로를 확보할 수 있도록 공간적 적용범위를 확대하여야 할 것이다.

I. Introduction

1. Background and objectives

The modern history of Korea's river management dates back to 1961 when the River Act was first legislated. The law has been amended many times since then, but flood control and the utilization of water resources remain as the central theme. River works in Korea are still focused on economic and structurally safe discharge of flood water, and little attention is being paid to environmental conservation or restoration.

Sand, gravel, and riverine spaces are considered as important components of water resources in this country. Many local governments issue permits for sand and gravel mining as a means of increasing revenue, or carry out river engineering projects in order to exploit sand and gravel deposited on or near river channels. Reclaiming floodplains is considered even more essential than sand mining especially in large cities where demand for new urban land is extremely high.

Since the so-called Han River comprehensive development project was completed in 1986, the construction of river front parks and sports fields on river terraces has become an essential part of urban river engineering projects. But only limited attention is being paid to the conservation or restoration of river ecosystems destructed during rapid industrialization and urbanization of this country.

When developing a river engineering project, survey and evaluation of river environment such as water quality, morphology, ecosystem, cultural resources, and aesthetic quality is essential (U.S. Army Corps of Engineers, 1989). Flood

control and water resource utilization are the main theme of the River Maintenance Master Plan required by the River Act of Korea, surveys for the master plan are limited to only the collection of data directly related to the computation of discharge volume and structural safety of river engineering works.

The survey and evaluation of the ecological, cultural, and aesthetic quality of a river is evaluated at the environmental impact study of a river engineering project, which is required only for very large scale development projects and is notorious in this country for its inability to alleviate environmental impacts of such projects. Despite of strong oppositions of many ecologists against the so-called the Han River comprehensive development project and the Nakdong River barrage construction project in the mid 1980s, the environmental impact statements practically endorsed the projects (KECC, 1983). Thus migratory bird sanctuaries on the estuaries of both rivers were totally destroyed.

A new trend to review traditional river engineering works in terms of environmental conservation, and introduce river restoration works applied in other countries to Korea can be observed these days. Much attention is being paid to the negative impacts of traditional river engineering projects (Park, 1996a; 1996b; Lee, 1994; Lee, et al., 1993a; 1993b). River restoration techniques applied in European countries and Japan have been introduced to Korea (MOC, 1991; 1992, 1993, 1994; MOE, 1995; MOCT, 1995; 1996). Some of the restoration techniques have been tested in selected urban rivers, but the result is not always satisfactory. Environmental groups interested in river restoration activities such as headwaters restoration or water pollution control are also busy at work since the early 1990s.

The objectives of this study are to investigate the status and ecological impact of the traditional river engineering projects in Korea, to evaluate recently completed river restoration projects, and to present future directions for such restoration projects.

2. Definitions

All river works carried out based on regulations of the River Act and the Small Stream Maintenance Act can be directly translated to English as river maintenance works. Such works usually employs structural means to ensure economic and safe discharge of flood water, and the utilization of water resources

and the construction of water front recreational spaces are also included in this type of river works. Lower channels are usually protected by solid materials such as concrete blocks, gabions, and crushed stones. The outcomes of such projects are characterized by uniform flow, depth, substrate, and aquatic habitat. Such river works insensitive to river ecosystem are called river engineering projects in this paper.

On the other hand, river restoration projects are river works based on the philosophy of *Naturnaher Wasserbau* developed in Germany and Switzerland since 1970s. The most important goal of this approach is to restore or revitalize river ecosystem through the creation of a diverse river environment very close to natural conditions. This approach is expected to supplement the shortcomings of the traditional river engineering works. Usually mixture of plant materials and hard materials such as concrete and stones are used for their potential to restore riparian ecosystem and to protect river banks against river flow. River restoration works are not limited to revetment only, but includes the construction of bypass or detention ponds and the management of banks and river terraces for the ecosystem conservation.

II. Outlines of rivers and river engineering in Korea

1. Dimensions of river restoration

Boon (1992) presented, based on Ward(1989), a five-dimensional approach for river conservation: longitudinal, lateral, vertical, temporal, and conceptual components. As can be seen from 〈Fig. 1〉, the five dimensional approach is modified for this study to represent two components related to water and three components related to riverine spaces.

The river restoration of small and medium sized urban rivers in Korea is heavily depend upon both water volume and water quality. First, water quality of urban rivers in this country is an important limiting factor for aquatic communities. Recent signs of water quality improvement of urban rivers can remove the first obstacle of river restoration in Korea.

Second, discharge volumes of most urban streams during dry seasons are inadequate to support healthy river ecosystems. Exposed river bed can be seen

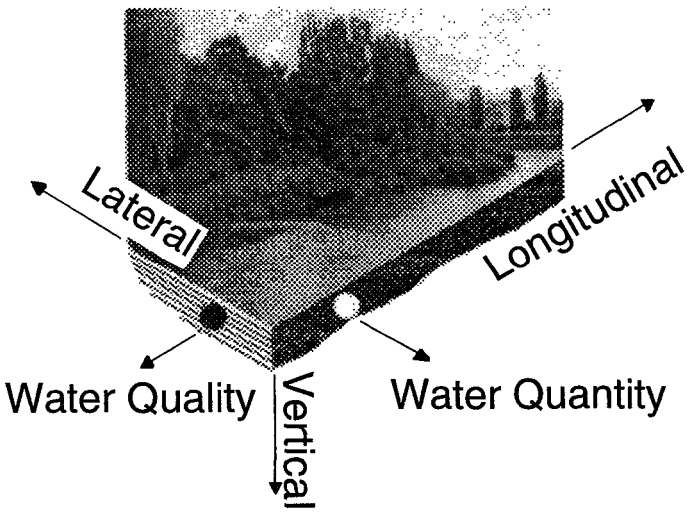
from upstreams of urban rivers during dry seasons. The increasing volume of water uptake and the construction of huge sewage treatment plants aggravates the water shortage problem of urban rivers. Maintaining the minimum desirable level of discharge during dry seasons is as important as the control of water pollution.

Longitudinal, lateral, and vertical dimensions of river restoration are the same as proposed by Boon (1992). First, longitudinal dimension is directly related to velocity, scouring, and sedimentation of rivers. River engineering projects usually include straightening and the construction of cross sectional structures such as weirs. The former increases the slope of a river bed and speeds up velocity, but the latter causes the opposite effect. Pools and ripples formed in natural, meandering rivers are destroyed in both cases and diverse aquatic habitats degrade to a very simple one.

Second, lateral dimension of a river is closely related to development pressure of the area. Since floodplains are considered as one of the ideal sites for urban expansion, most river engineering projects decrease lateral dimensions of urban rivers. Many parks, sports fields, parking lots and roads have been built on river terraces of flood frequency of less than a year. The combined outcomes of decreasing width of a river and the introduction of land use types incompatible to river ecosystem causes significant side impacts to sensitive aquatic ecosystems.

Third, vertical dimension of a river is also closely related to the above mentioned lateral dimension. If floodplains were developed for urban uses or intensive human activities were introduced to water front, the vertical dimension of the channel should be expanded, either by excavating stream bed or embanking, to ensure safe discharge of flood water. Usually banking operations on river terraces are carried out with substrate materials excavated from the river bed to decrease flood frequency on river terraces. In many cases sand and gravel deposited on river channels are mined to increase the revenue of local governments. Weirs across river channels result in stagnant pools with simple substrates.

Therefore, a stream with a variable depth, slope, and velocity transforms to a channel similar to a canal, usually protected by concrete revetment. In short, traditional river engineering projects produce simple and monotonous riverine



〈Fig. 1〉 Conceptual diagram for River Restoration

spaces where only limited species can survive.

2. Types of river restoration projects

River restoration projects can be classified into three groups. The first type are confined to existing river channel made by previous channelization works. River works designed to overcome the shortcomings of concrete revetments, in terms of habitat diversity, and to create diverse edge conditions by utilizing porous materials and plant materials are belong to this group. River works designed to create meanders, ripples, and pools within present river channels are also belong to this type.

The second group of river restoration projects includes the first type of river works and also designed to create diverse habitats on river terraces so that original species composition of the river channel and terraces can be restored. This type of river works can tolerate very little human activities and intervention, and riparian vegetation should be allowed to recover. But the situation in Korea is far from this ideal. Most channelized rivers and streams have very limited margin of safety in terms of flood water discharge, planting of trees higher than one meter on river terraces is prohibited. Natural growth of bushes on river banks are periodically cleared in Korea.

The third group of river restoration projects includes the first and second type river works and also designed to cut off outside forces which can threaten sensitive riparian ecosystem, and to connect fragmented riparian plant communities and regional ecosystem. Such projects can only be made possible by restoring riparian ecosystem of at least part of old floodplan.

3. Characteristics of Korean rivers

About 66% of the total precipitation of Korea comes during monsoon season, which is from June to September. The total precipitation of Korea is 114 billion metric tons per year, and total discharge volume is 58% of total precipitation or 66.2 billion metric tons. As can be seen from 〈Table 1〉, the five major rivers of Korea have a very large river regime coefficient, the ratio between minimum discharge volume to the maximum discharge of a river.

The importance of flood control during summer can be understood easily, thus most rivers have huge cross sections. On the other hand, discharge volume during dry season of nine months is 39% of yearly discharge volume, and only 10% of discharge during four months from November to February (MOC, 1994). Discharge volume of other seasons are usually so small that much of the river beds are exposed. Such a flow deficiency increases water pollution level and devastates most of the river's aquatic ecosystem.

Thus river managers of this country is faced with two contradictory problems: flood control for summer season and the maintenance of an optimum discharge level for aquatic ecosystem during other seasons. Such a problem has been partly solved by employing the double trapezoidal cross section channelization.

〈Table 1〉 Characteristics of Major Rivers of Korea

Rivers	Length (Km)	Watershed (Km^2)	Average Rainfall(mm)	River Regime Coefficient (Min. Flow : Max. Flow)
Han River	470	26,919	1,200	1 : 393
Nakdong River	525	23,852	1,110	1 : 372
Kum River	401	9,886	1,200	1 : 298
Seomjin River	212	4,897	1,280	1 : 715
Youngsan River	115	2,798	1,270	1 : 682

Source: Sunu, Jungho, 1995, *Hydrology*, Dongmyongsa.

4. Legal classification of rivers

Based on legal framework of Korea, rivers and streams of this country can be classified into three groups: rivers regulated by the River Act, small streams regulated by Small Stream Maintenance Act, and creeks not covered by the two laws. As can be seen from 〈Table 2〉, 3,964 rivers and streams of 30,416 km long are regulated by the River Act, and these are also classified, based on their size and administrative responsibility, into three classes. The Class I rivers encompass large and important rivers in terms of flood control and water resource utilization, and are controled by the Minister of the MOCT(Ministry of Construction and Transportation). Streams regulated by the Small Stream Maintenance Act are 25,455 streams and 39,500 km long.

Both acts require so-called river maintenance works which employ various types

〈Table 2〉 Legal Status of Rivers and River Engineering Works in Korea

Legislations	Types of Rivers	Numbers	Length (km)	Rivers Require Flood Control (km)	River Works Completed		Administrator
					Length (km)	Percent (%)	
River Act	Subtotal	3,964	30,416	35,782	20,881	58	
	Class I	62	2,858	2,750	2,576	94	Minister, Ministry of Construction and Transportation
	Class II	55	1,320	1,278	978	77	Mayors of Metropolitan Cities or Governors of Provinces
	Class III	3,847	26,238	31,753	17,327	55	Mayors of Metropolitan Cities or Governors of Provinces
Small Stream Maintenance Act	Subtotal	25,455	39,500		11,773	30	
	Class IV	1,284	5,724		2,428	42	Mayor
	Class V	5,625	11,690		3,932	34	Mayor
	Class VI	18,906	22,086		5,413	24	Mayor
Total		29,419	69,916				

Source: Ministry of Construction, 1994, *Survey and Research on Natural River Channel Design Techniques and the Relationship between Flow Volume and Water Quality*, pp.13-16, modified

of structural means for flood control and water resource utilization. The act requires to identify segments of rivers where flood control structures are needed. The percentage of river length where flood control works have been completed to the total length of the river requires flood control works are called river maintenance percentage. Flood control works for 20,880 km, or 58% of river length required by the River Act had been completed by the end of 1993. And flood control works for 11,733km of small streams had been completed by the end of 1993, thus so-called maintenance percentage of small rivers were 30% (MOC, 1994).

The total length of urban rivers and streams are 2,973 km long, and flood control works for the urban rivers were nearly completed by the early 1993. And 7.3% or 216 km long stretches of urban rivers have facilities for water-related recreation activities (MOE 1997).

5. Activities related to river environment

(1) Reclamation

Floodplains have been an important source of land for new urban development in Korea during rapid industrialization and urbanization of Korea since the early 1960s. Properties located on floodplains are relatively cheap compared to agricultural fields or rolling lands, and most properties on floodplains are under public or national ownership. Thus developers, usually local governments or semi-public organizations, can acquire extensive areas of developable land at a relatively low price, and reap huge profit from the project.

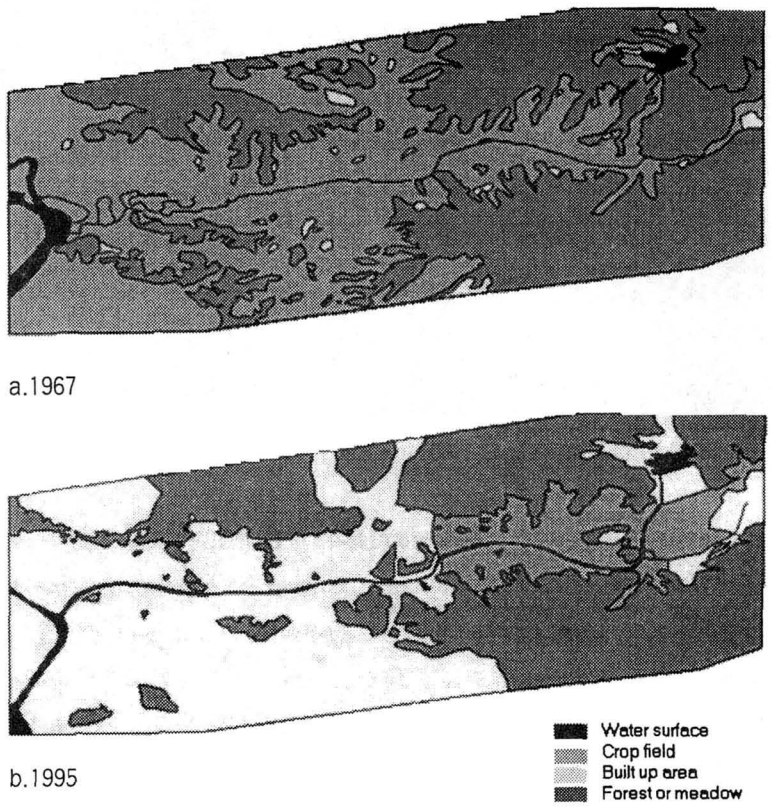
Since the first large scale residential development on reclaimed lands along the Han River in Seoul started in 1963, more than 7,500,000m^2 of residential areas has been developed on reclaimed lands in Youido, Chungjido, Seobinggo, Banpo, Sungsoo, Apgujung, Chamsil, Pungnap, and Kayang areas (Kim, 1984). The width of the Han River at the Indo Bridge was 1,300m when the bank at that point were constructed after the great flood of 1925. But the width was narrowed to 970m during the land reclamation period of 1960s (KECC, 1984). The banking of about two meters is not uncommon in many residential area development projects such as the Mokdong area located on floodplains of the Ahnyang Stream.

Much of new lands for urban expansion have been provided through the

reclamation of floodplains, which is regulated by the Public Water Surface Management Act. Extensive channelization works are needed for these projects (Gardiner, 1991): meandering river channels are straightened, river beds are excavated, steep and high banks are constructed, and concrete revetments are installed to prevent flooding of reclaimed lands. The construction of relatively small detention ponds equipped with powerful pumping stations is a standard practice for most riverine developments.

(2) Channelization

The channelization process of the Yangjae Stream during 1967-1995 period is shown on 〈Fig. 2〉. Many braided, meandering channels could be identified near the junction of Tan Stream map of 1967. As can be seen from 〈Table 3〉, builtup areas increased from 1.36% to 47.13% of the watershed. And most agricultural



〈Fig. 2〉 Change of Land Cover and Channel of the Yangjae Stream Watershed Identified from Aerophoto

〈Table 3〉 Change of Land Cover in the Yangjae Stream Watershed (1967 - 1995)

(Unit: %)

Landuse \ Year	1967 (A)	1995 (B)	Change (B)-(A)
Water surface	1.67	1.43	−0.24
Crop field	49.64	9.88	−39.76
Built-up area	1.36	47.13	45.77
Forest or meadow	47.33	41.56	−5.77
Total	100.00	100.00	0

〈Fig. 3〉 Site of Traditional River Improvement at the Yeosu Stream, Seongnam City

fields along the Yangjae Stream converted to builtup areas and the river channel has been straightened and channelized. As can be seen from 〈Fig. 3〉, the banks of the lower channel are riveted with concrete blocks. Morphological characteristics of a natural channel such as pool, riffle, and point bar are no longer present on this channel. Urban rivers with such a simple channel can support only a fraction of species which can be found in natural stream.

(3) Culvertization of streams

A great lengths of Korean urban streams have been culvertized to construct urban streets and parking lots or simply to cover up severely polluted segments of

urban streams. As shown on 〈Table 4〉, about 28% or 67.7km of the total length of 237.7km of the 34 tributaries of the Han River in Seoul has been culvertized. The entire length of the following six streams, Bongwon Stream, Chunggye Stream, Myonmok Stream, Wolgok Stream, Nokburn Stream, and Sihung Stream

〈Table 4〉 Calvertization of Streams in Seoul Metropolitan City

Watersheds	Streams	Length (m)	Calvertized Stretch		Percent of Calvertized Stretch (%)	Land Use Types
			Width (m)	Length (m)		
Han River	Hongjae	11,950	3-50	3,362	28.1	Road
Jungrang	Bongwon	1,250	25	1,250	100	Road
	Chunnong	1,850	9-42	1,300	71.2	Road, Parking
	Chunggae	3,670	16-18	5,480	100	Road
	Myonmok	1,900	14-23	1,900	100	Road
	Ui	8,330	15-40	749	8.9	Parking
	Panghak	2,980	5-9	1,070	35.9	Road
	Tanghyun	6,100	6-26	2,940	48.2	Road
	Tobong	3,323	15	120	3.6	Parking
Chunggae	Sungbuk	5,110	3-18	3,660	71.6	Road
	Jungrung	11,940	4-37	4,205	35.2	Road
Ui	Kao Stream	2,016	5-12	1,635	81.1	Road
	Daedong	1,600	5	500	31.3	Road
	Hwagye	2,800	6-24	2,390	85.4	Road
Dorim	Daebang	7,400	6-25	4,493	60.7	Road
	Dorim	14,200	19-30	5,662	39.9	Road
	Bongchun	5,150	4-46	4,901	95.2	Road
Banpo	Sadang	7,470	7-26	3,500	46.8	Road
	Banpo	3,770	18	1,100	29.2	Road
Hongje	Bulkwang	8,790	3-20	4,080	46.4	Road
Jungrung	Wolgok	2,727	6-17	3,380	100	Road
Bulkwang	Nokburn	2,200	8-24	2,940	100	Road
Kaehwa	Oryu	3,000	2-14	2,160	72.0	Road
Ahnyang	Sihung	2,050	3-30	2,795	100	Road
Yangjae	Yeoui	3,300	30	454	13.8	Road
Sungnae	Sungnae	8,220	5-10	1,690	20.6	Road
Total				67,716		

Source : Seoul Development Institute, 1996, *A Study on River Restoration Policy of Seoul*, p.23. (in Korean)

have been culvertized. More than 80% of the lengths of Hwagye Stream, Kao Stream, and Bongchun Stream have been culvertized (Seoul Development Institute, 1996).

All this culvertization deprives the two essential factors to maintain streams in an ecologically healthy state. First, the solar radiation is entirely cut off at such stream segments, and the capability of hydrophytes to remove water pollutants and provide dissolved oxygen are lost. No decent life form can survive in such a devastated and anaerobic condition. Second, the sewer lines constructed in most polluted and culvertized streams reduce the amount of river flow significantly so that river beds are exposed except on rainy days. Thus number of aquatic species in such rivers diminishes significantly.

(4) Construction of huge sewage treatment plants

The most important river management task of this country during the last decade has been the construction of sewage treatment plants. Four treatment plants with capacity of 3,710,000 m^3/day treated 67% of total sewage discharge in Seoul at the end of 1995. When the expansion projects of existing treatment plants are completed by the end of 1997, additional capacity of 2,100,000 m^3/day will be increased (Kim, 1996). The capacity of Kayang sewage treatment plant at that time will be 2,000,000 m^3/day, which is the second largest capacity in the world.

The construction of huge treatment plants also requires an extensive networks of sewage pipes, and discharge volume on the upstreams of a plant inevitably diminishes drastically. Such condition causes severe water pollution and devastates most freshwater ecosystem. Thus to maintain an optimum discharge volume during dry season is essential for the conservation of river ecosystem.

III. Survey on River Projects

1. River engineering projects

At this study, emphasis was focused on riverine spaces of five urban rivers where so-called river maintenance projects were under construction or completed recently. Selected five urban rivers were the Han River of Seoul, Shin Stream of Taegu, Kwangju Stream of Kwangju, Musim Stream of Cheongju, and Namdae Stream of Kangrung. The Han River engineering project carried out 1982-1986 can

〈Table 5〉 Outlines of Surveyed Rivers and Streams

River or Stream	Length of River Segment(km)	Width (m)		Flood Flow (CMS)	Flood Frequency
		Bank	Lower Channel		
Han River	36.0	800~1,500	725~1,175	37,000	200yr
Musim Stream	17.5	154	45	1,043	80yr
Kwangju Stream	12.3	45~220	25~70	850	100yr
Shin Stream	12.5	80~240	70~110	1,010	100yr
Namdae Stream	8.8	148~313	70~80	1,630	100yr

〈Table 6〉 Methods to Maintain Constant Flow during Low Flow Periods

Rivers	Mean Flow (cms)	Source of Additional Water During Low Flow Periods	Means for Constant Water Level
Han River	250	Increase discharge volume at Paldang Dam	Underwater weirs at Chamsil and Yanghwa Br.
Musim Stream (Mouth)[1)]	1.3	Intake from Daechung Dam (4.83cms)	Irrigation weir at Pangseo Br.
Kwangju Stream[2)]	0.8	-	Rubber weir
Shin Stream (Mouth)[3)]	1.19	Ground water pumping (10,000t/day)	—
Namdae Stream[4)]	56.80	—	Rubber weir

Source 1) Office of Environment, 1987, *Musim Stream Water Management Master Plan.*
2) Chunlanam Province, 1985, *Kwangju Stream River Channel Engineering Master Plan.*
3) Taegu Metropolitan City, Unpublished Document.
4) Kwangwon Province, 1995, *Namdaechun Stream River Channel Engineering Master Plan and Design.*

be considered as the model project for other urban river projects. Study areas were confined to river corridors within their jurisdictional boundaries.

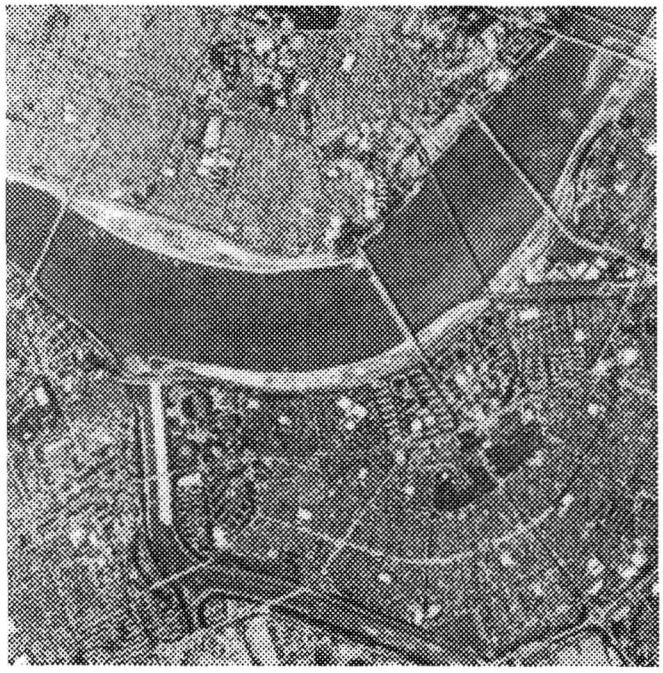
Large-scale sewage treatment plants equipped with extensive network of sewage pipes are being operational except for the Namdae Stream where a plant is under construction. But the water quality of many segments of the rivers surveyed are so bad that only the most hardy aquatic species can be found. Large scale algal blooms and fish-kills during summer dry spells are not uncommon in these rivers.

Fortunately, the huge investment for the control of water pollution is being started to pay off. Signs of water quality improvement and partial recovery of aquatic community can be observed.

(1) Transportational use of hard paved terraces

Many urban expressways and subway routes are located on part of river terraces or banks. Elevated expressways are also constructed along river coridors. The length of roads constructed along river channels were 159km, or about 67% of total length of river channels in Seoul, at the end of 1992, of which 49km were elevated expressways.

Large scale overflow parking lots are constructed at all river terraces of the five surveyed streams. Such practice are caused by the severe shortage of parking lots in urban areas. The practice of constructing overflow parking lots on river terraces of urban streams is inevitable till a long-debated legislation which requires to secure a parking space when one buys a vehicle. As can be seen from 〈Fig. 4〉, most white reflected surfaces on river terraces are either concrete paved parking lots or roads.



〈Fig. 4〉 Hard Paved and Nuded Areas Used for Parking or Roads on the Han River Terraces, Identified from a KVR-1000 Image of 1992.

(2) Incompatible land use for riverine areas

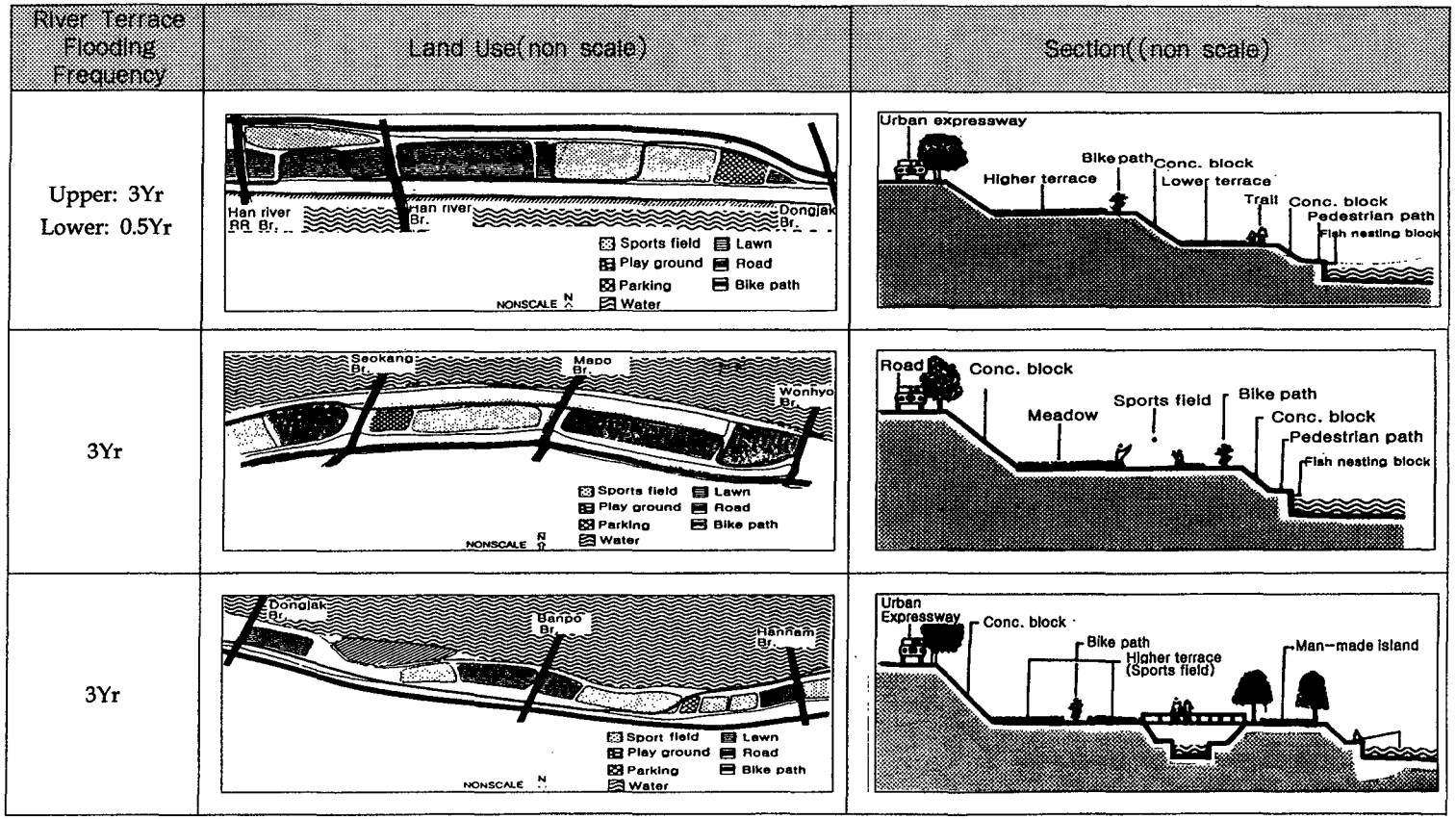
It was found that sports fields, water front parks, and parking lots had been constructed on all river terraces of five surveyed sites. Most natural landforms and native wetland vegetation were removed. And most non-paved areas were maintained for plant beds or Zoysia grass, both of which are intolerant to wet soil conditions and flooding and require excessive management activities. Such areas are usually so heavily tramped that bare soil is exposed. Thus it is hard to observe any signs of a healthy river ecosystem.

○Han River, Seoul

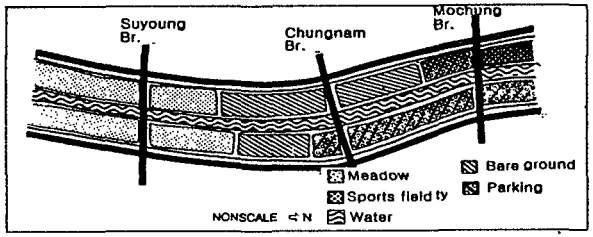
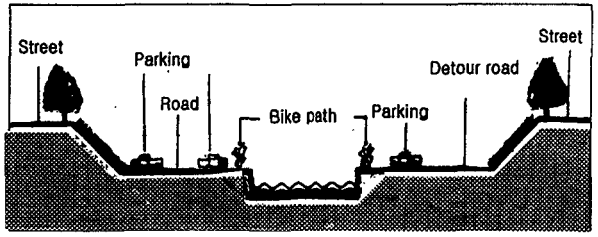
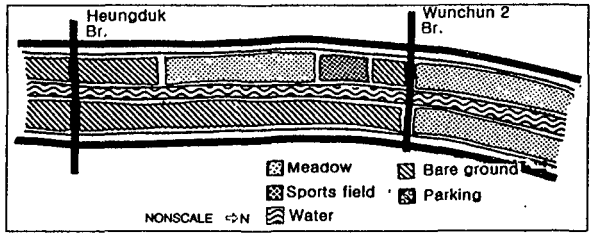
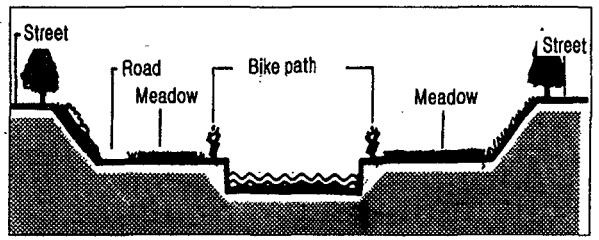
The Han River in Seoul was developed by the so-called Han River comprehensive development plan. One of the most important goals of the project was to convert a free flowing urban river to a channelized stream with constant depth and width. All river structures were designed based on 37,000m^3/sec flood, but normal discharge was designed to 200m^3/sec. Two underwater weirs were constructed to maintain the depth of 2.5m of the lower channel. The width of lower channel varies from 725m at Youngdong Bridge to 1,175m at Seoul Grand Bridge. Two levels of river terraces were constructed by banking dredged materials from the lower channel. Lower terraces were covered with wet meadow grasses, and the upper terraces were mainly developed for intensive uses such as lawn grounds, flower beds, sports fields, swimming pools, play grounds, parking lots, road, pedestrian trails and bike path. Typical cross section and plan can be seen from 〈Fig. 5〉. Such a river section of double trapezoidal shapes was emulated from similar development at Yodogawa in Osaka and Sinanogawa in Niigata in 1950s (Ahn, 1983), and many urban rivers in Korea have been developed based on this model.

○Musim Stream, Cheongju

In the case of the Musim Stream in Cheongju City, the construction of a riverside park was included as a part of the river improvement project. But the park is not yet constructed due to financing problem of the local government. The present status of Musim Stream is presented at 〈Fig. 6〉. The area marked as unmanaged meadows and bare soil is the site of the proposed park. Much of the river terraces close to CBD are used for sports fields, bike path, detour road, and parking lots. The detour road and parking lots were constructed to relieve traffic



〈Fig. 5〉 Outlines of the River Engineering Project of Han River, Seoul

River Terrace Flooding Frequency	Land Use(non scale)	Section((non scale)
0.3Yr		
0.3Yr		

〈Fig. 6〉 Outline of the River Engineering Project of Musim Stream, Cheongju

congestion of the CBD.

○Kwangju Stream, Kwangju

As can be seen from 〈Fig. 7〉, much of this site is covered with concrete structures. Lower channel is protected by concrete retaining walls and many weirs are constructed across the lower channel. Roads on both banks have been expanded by constructing cantilevered roads on both sides. A bike path is constructed at the downstream segment of the river. Parking lots have been constructed on river terraces and only a small portion of the terrace is covered with *Zoysia* grass.

○Shin Stream, Taegu

The total size of river terraces constructed at this site is 823,000m^2, many type of user facilities have been constructed on the site and most of them are heavily used by visitors of all ages. As can be seen from 〈Fig. 8〉, sixteen parking areas of 50,030m^2, 42 sports fields, fourteen hard paved plazas, and bike path of 132,242m long and pedestrian path of 1,036m long have been constructed. But river bed is almost always exposed because of the water diversion at a huge upstream pumping station constructed for industrial use at the east coast of the region.

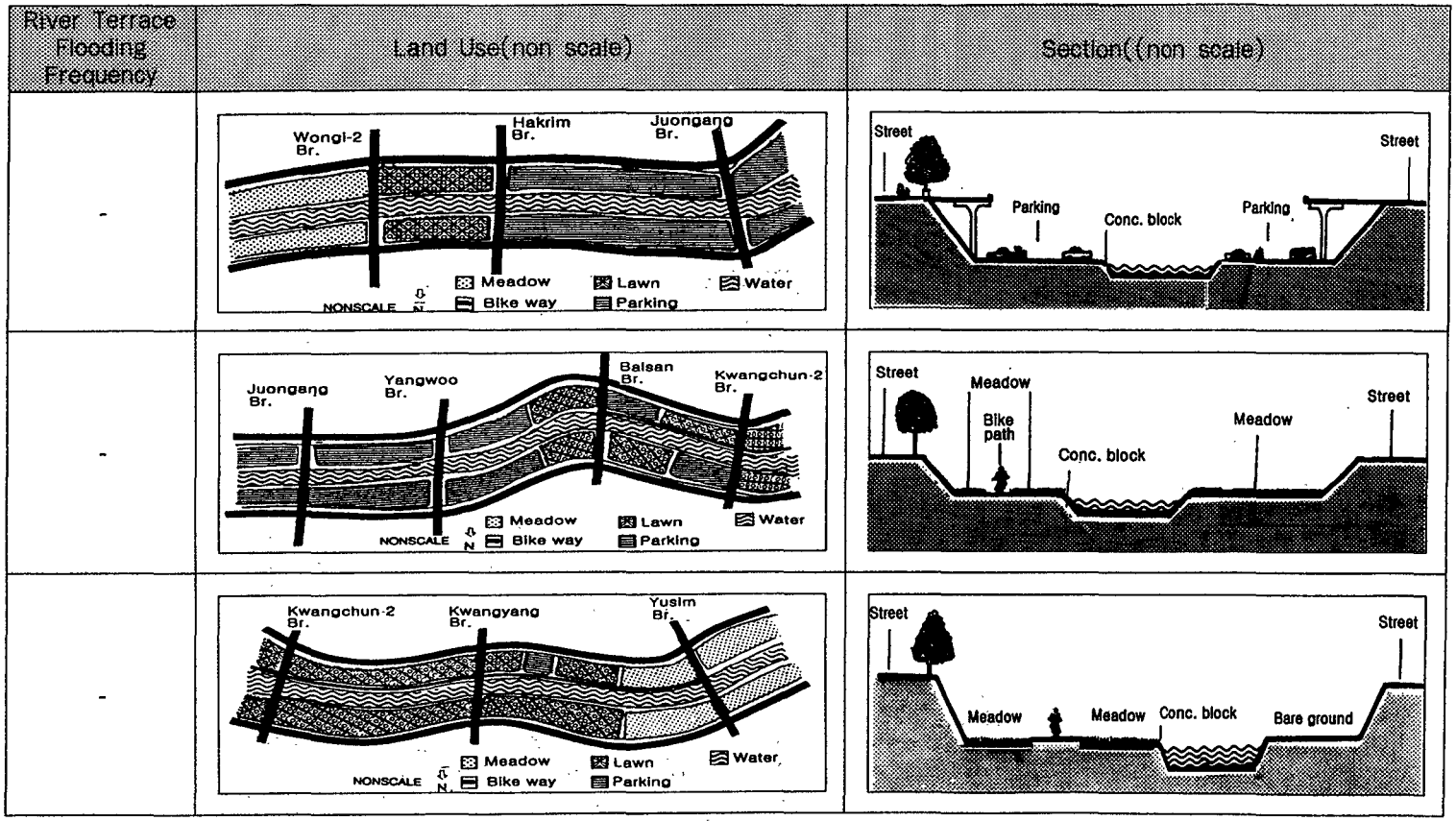
○Namdae Stream, Kangrung

As can be seen from 〈Fig. 9〉, river terraces have been constructed on both sides of lower channel, and parking lots were constructed on hard paved areas for overflow parking areas of the small city. Other side of the terrace not used for sports fields were covered with wet meadow grasses. Except parking lots, only a few anglers visit this site.

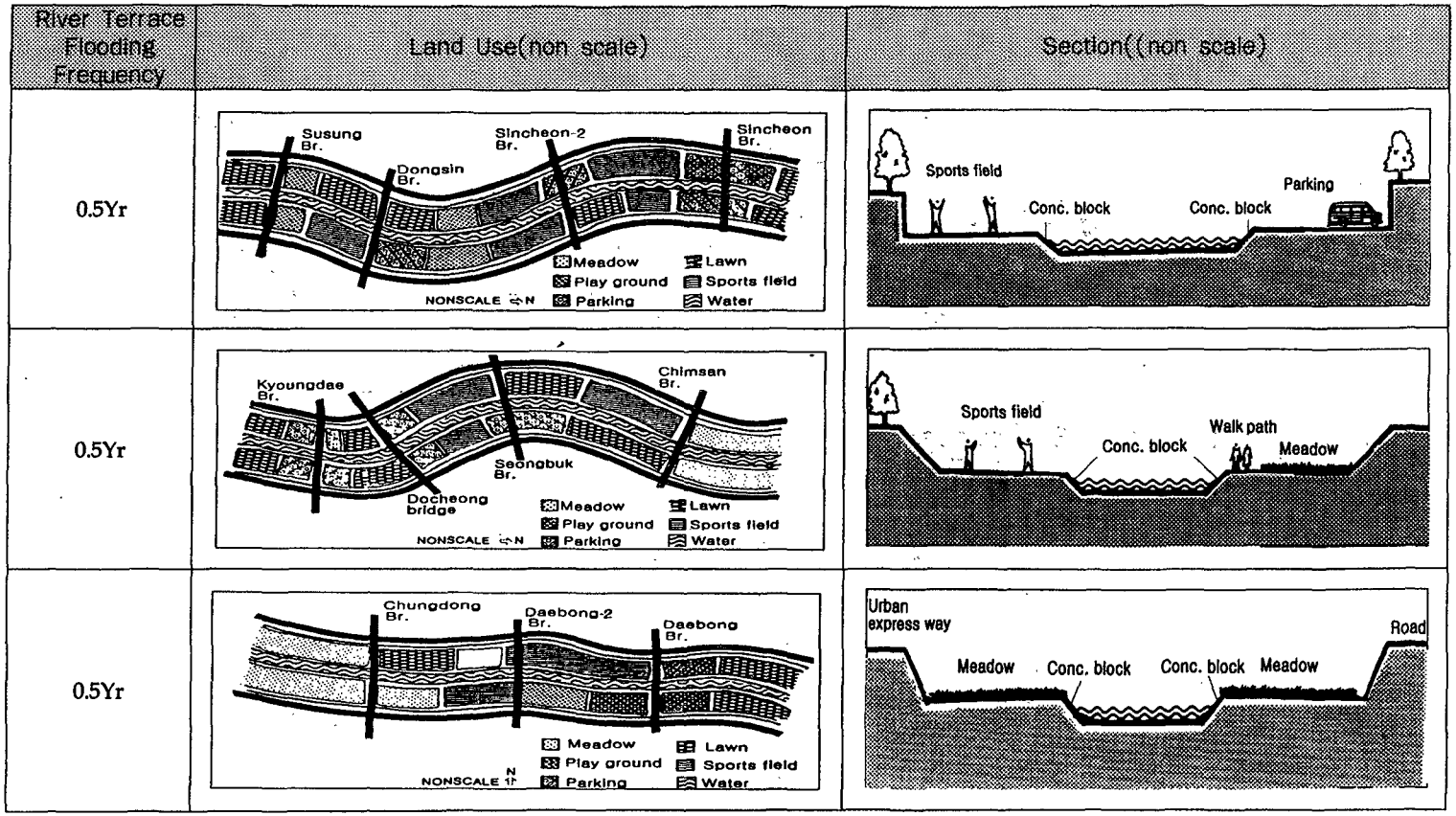
(3) Incompatible planting and management

Most riparian vegetation of the Han River was destroyed by the so-called Han River comprehensive development project. Especially the construction of urban expressways of 6 or 8 lane on both banks resulted in monotonous, artificial urban landscape. Thus a planting plan along the river banks of the Han River was developed and implemented (Seoul, 1995). Since the most important goal of the plan was to enhance the visual quality of the river corridor, most effort was concentrated on the planting of street trees and flowering shrubs on river banks. Many flower beds on river terraces were also constructed.

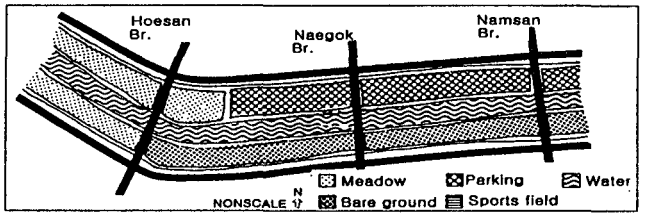
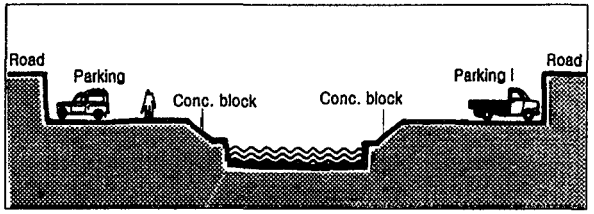
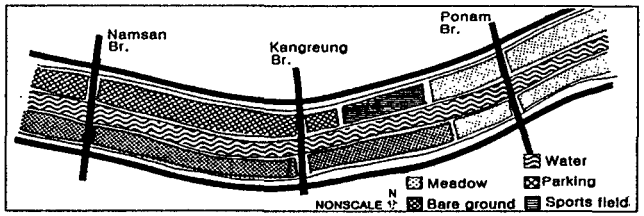
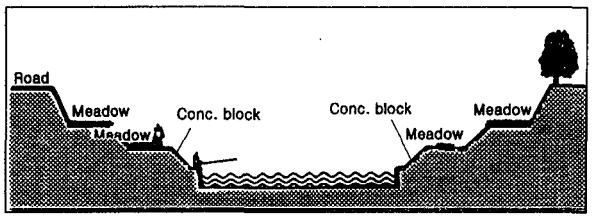
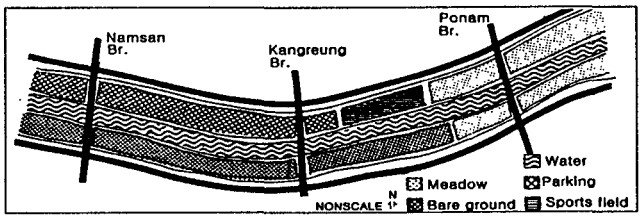
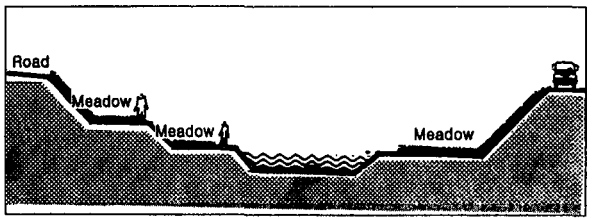
Very little attention has been paid to the restoration of riparian vegetation or



〈Fig. 7〉 Outlines of the River Engineering Project of Kwangju Stream, Kwangju



〈Fig. 8〉 Outlines of the River Engineering Project of Shin Stream, Taegu

River Terrace Flooding Frequency	Land Use(non scale)	Section(non scale)
0.5Yr		
0.5Yr		
0.5Yr		

〈Fig. 9〉 Outlines of the River Engineering Project of Namdae Stream, Kangrung

wildlife conservation. Meadow grasses are usually considered as weeds and being removed manually or by weed killers (Han River Management Office, no date). Fortunately, part of lawns, especially lower terraces and part of higher terraces where so-called recovery jobs after flooding are not intensive enough to suppress invading natural grasses, is being transformed naturally to wet meadow grasses.

(4) River structures unsuitable for fish migration

The structure of channelized streams become too simple to support diverse aquatic species. Most rapids and pools disappear. Most aquatic spawning grounds are either destroyed by sand and gravel mining or covered with layers of fine clay deposits. Shallow channels are fragmented by many weirs, and surface water may be found only on the direct upstream of weirs in many small and medium rivers during dry seasons. Such fragmentation of channel with weirs can prevent local migratory fishes such as 버들개(*Moroco lagowskii*), 피라미(*Zacco platypus*), 산천어(*Oncorhyncus masou v. ishikawai*) from moving to other segments of rivers if water quality improves. The task of restoring anadromous migratory fishes such as salmon and trout requires the improvement of all vertical structures in the routes for the targeted species.

2. River restoration projects

There is a growing concern for the river restoration by a selected group of academics, government officials in charge of river management at the Ministry of Environment, Ministry of Construction and Traffic, Ministry of Home Affairs, and a few local governments. As shown on 〈Table 7〉, some of the recent river restoration projects in Korea could be initiated, even as a pilot project or on test trials, by those interested participants.

Ministry of Construction and Transportation have continuously sponsored research projects on river restoration approaches since 1991, and the first on site river restoration experiment was implemented on 1995 at the test site of the Yangjae Stream, at Daechi-dong. In this project ten types of lower bank protection technique using natural materials were experimented.

The Ministry of Environment launched a three-year research project for river restoration techniques in 1995, and a research team composed of hydrologists; ecologists, and landscape architects has been organized for the survey,

〈Fig. 10〉 Site of River Restoration work at the Seongnae Stream

〈Fig. 11〉 Site of River Restoration Work at the Suwon Stream

〈Fig. 12〉 Site of River Restoration Work at the Youi Stream

development, testing, and monitoring. An experimental site was selected last year at the Yangjae Stream, in Kwacheon City, and various restoration techniques for lower channel restoration were applied with natural materials such as live willows, wood stakes and wooden groins, and boulders to create meandering, narrowed channel.

The Ministry of Home Affairs has the authority to manage small streams of Korea by the provision of the Small Stream Management Act. The ministry published a guide book in 1994, which shows that river engineering work are planned to implemented on 27,727km of small streams by 2016. Bad side of such an ambitious plan is that much of natural streams could be degraded if serious river restoration techniques were not applied.

A few local governments also are interested in river restoration works. Under the Yangjae Stream Park Plan prepared by Kangnam District Office, 2.34km long river segment was developed as a linear park on the river terraces, and a few restoration works such as meandering lower channel and vegetated lower bank protection with crushed stones were applied.

〈Table 7〉 Recent River Restoration Projects in Korea

Streams	Location	Types of river works	Vegetation Types	Project Administrator	Year
Yangjae Stream	· Daechi-dong, Kangnam-gu, S.M.C* · L = 50m	· Ten types of lower bank protection works using wood stakes, willow mattresses, stones, coir nets and rolls	· *Miscanthus sacchariflorus* · *Phragmites communis* · *Salix gracilistyla* · *Acorus calamus v. angustatus* · *Typha angustata*	· Kangnam District Office, Seoul · KICT**	1995
	· Kangnam-gu, S.M.C · L= 2,340m	· Meandering lower channel · Vegetated lower bank protection with crushed stone · River front parks	· *Salix gracilistyla,* · *Phragmites communis,* · *Typha orientalis* · *Oenanthe javanica*	· Kangnam District Office, S.M.C	1996 - 1997
	· Burim-dong, City of Kwachon · L = 200m	· Meandering lower channel · Many types of lower bank revetment with vegetation	· *Phragmites japonica* · *Salix gracilistyla* · *Acorus calamus v. angustatus* · *Iris ensata v. spontanea* · *Lythrum salicaria* · *Scirpus triqueter* · *Zizania latifolia*	· City of Kwachon · KICT	1996 - 1997
Ahnyang Stream	· Kwangmyong Br., City of Kwangmyeong · L= 50m	· Meandering lower channel · Vegetated lower bank protection with coir roll	· *Salix gracilistyla*	· City of Kwangmyeong	1995
Youi Stream	· Poi-dong, Seocho district, Seoul · L= 1,810m	· Vegetated lower bank protection with coir roll or crushed stone	· *Salix gracilistyla* · *Phragmites communis*	· Seocho District Office, S.M.C	1995
Suwon Stream	· Yeonmu-dong and Younghwa-dong, Changan District, Suwon · L= 1,200m	· Meandering lower channel · Vegetated boulder revetment on concrete footing · Native grasses on river terraces · Lower bank work with boulder, hydrophytes, wood stakes, and seed attached mattresses · Creation of rapids and pools · Boulders on river bed		· City of Suwon	1996

*Seoul Metropolitan City
**Korea Institute of Construction Technology

In the case of Suwon Stream, original plan to culvertize the stream and construct parking lots and road was canceled, because of large scale public opposition. Recently a river park was opened instead. Stream segment of 1.2km long was developed to have pedestrian path on river terraces. Boulders were spreaded out on lower channel bottom, and boulder dams, rapids and pools, and vegetated boulder rivetment was installed. But piled-up stone walls were left unchanged.

Seocho District Office of Seoul implemented a restoration work of the Youi Stream that included meandering low channel, spreading out boulders for the creation of microhabitats, and vegetated lower bank protection with coir rolls or crushed stones. And pedestrian path paved with concrete blocks was also constructed on the half of stream terraces. But the concrete blocks protecting high banks were left as before.

A very limited experimental restoration work was also applied at the Ahnyang Stream where 50m length of the concrete block rivetment was replaced with vegetated coir rolls.

The characteristics of the river restoration works carried out thus far in Korea can be classified as follows. First, most restoration works are usually confined to lower channels and techniques related to meandering low channels, creation of rapids and pools, substrate modification, and boulder dam are utilized. Second, river works for lower bank protection with vegetated porous and natural materials have been applied at many sites. Third, land use types not related to river ecosystem occupies too much riverine spaces, and much of the river terraces changed to dry grassland, which together degrades river ecosystem severely. Finally, very little attention has been paid for the restoration of original riparian vegetation on river terraces or banks or the networking of fragmented riparian vegetation to nearby regional ecosystem.

IV. Conclusions

The objectives of this study were to investigate the status and ecological impact of the traditional river engineering projects in Korea, and to evaluate recently completed river restoration projects.

Five urban rivers were surveyed to evaluate river engineering projects of Korea. The sites are the Han River of Seoul, Musim Stream of Cheongju, Shin Stream of Taegu, Kwangju Stream of Kwangju, and Namdae Stream of Kangrung. It could be concluded that the traditional river engineering projects cause irreversible negative impacts on river ecosystems. First, channelization with double trapezoidal cross section significantly reduces and simplifies aquatic habitat of nearly stagnant canals surrounded by river terraces covered with dry meadow grasses and lawns. Usually diverse aquatic habitat of natural rivers are destroyed drastically, and weirs and concrete embankments result in fragmented habitats. Second, incompatible land use types such as urban expressways, overflow parking lots, and athletic fields occupy too much riverine spaces. Third, inappropriate selection of plant materials and management practices which require intensive labor, fertilizer, and even weed killers prevent the development of natural riverine vegetation

The increasing social awareness on river restoration in Korea results in several river restoration works recently. River works applied to Yangjae Stream, Ahnyang Stream, Youi Stream, and Suwon Stream were surveyed for this research. It might be too early to draw any meaningful conclusions, but following characteristics could be identified. First, techniques related to the creation of meandering low channels, rapids and pools, diverse substrate are applied to lower channels. Second, embankments with live willows, other organic materials such as coir rolls and wood stakes were employed for the protection of lower channels. Third, river terraces are mainly used for ordinary urban outdoor recreation activities such as hiking, biking, and athletic fields, and very little attention is being paid to the ecological restoration of river terraces and beyond. Thus future river restoration works should be expanded to include river terraces and ecologically meaningful patch habitats on old river corridors, and to interconnect riverine ecosystem with regional ecosystem so that flora and fauna species could move along and across river channels.

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